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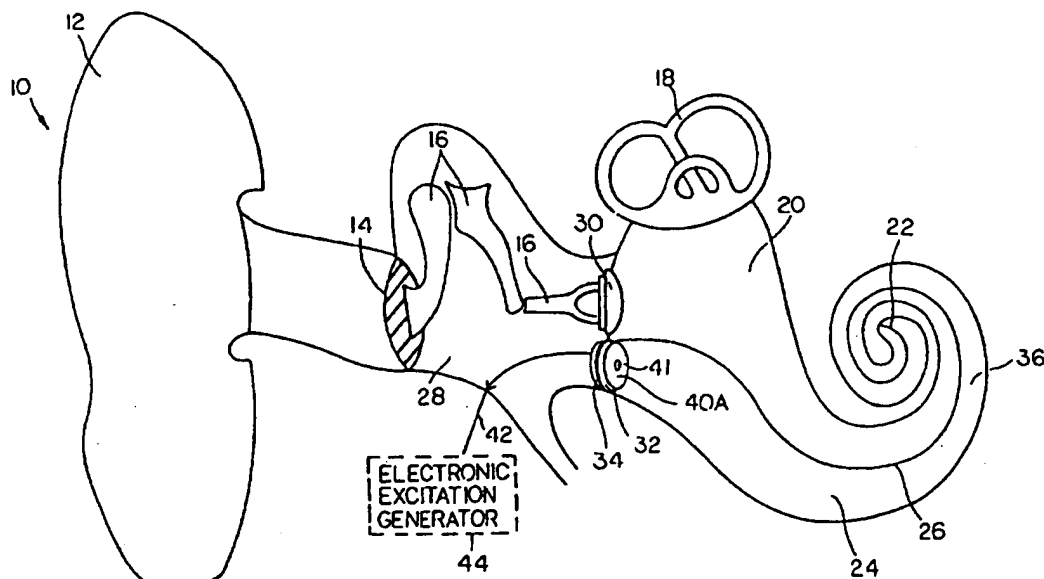
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(54) Title: IMPLANTABLE MICROPHONE FOR COCHLEAR IMPLANTS AND THE LIKE



(57) Abstract

A system for assisting a person with a hearing disability includes an implantable microphone (40A) which senses sounds by monitoring pressure variations in the cochlear fluid (36). The electrical signal generated by the microphone (40A) is processed and used by a signal generator (44), such as a cochlear implant to generate excitation signals for the patient. In this manner, external microphones, used in prior art systems, are eliminated.

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IMPLANTABLE MICROPHONE FOR COCHLEAR IMPLANTS AND THE LIKE

BACKGROUND OF THE INVENTION

A. Field of Invention

- 5 This invention pertains to a microphone which may be implanted in the ear of a patient. The microphone is preferably used in conjunction with a cochlear implant, although it may be used for other purposes as well.

B. Description of the Prior Art

- The subject invention pertains primarily to cochlear implant systems.
- 10 These cochlear systems are used to provide therapy to a patient suffering from hearing loss. All of these systems require two sections: an internal or implanted section, and an external section. The external section includes a microphone for receiving ambient sounds and converting them to electrical signals. These electrical signals are processed and sent to the implanted section. The
- 15 implanted section then generates excitation signals used to electrically excite the cochlear nerve of the patient through an electrode array.

- A major disadvantage of these systems is that the external section is fairly visible and thus provides a source of embarrassment to the patient. Additionally, a communication channel must be established between the
- 20 external and internal section either by a hardwired connection or by using electromagnetic means such as radio waves or inductive coupling. In either case additional circuitry is required increasing the complexity of the system. Moreover, the direct coupling requires a mechanical connection through the patient's skin which may lead to infections and other complications. These
- 25 problems could be eliminated by providing a fully implanted cochlear system, i.e., a system wherein the microphone is not external but is surgically implanted. Some early attempts have been made in this direction, for example by implanting a microphone which uses the ear drum as the microphone membrane with either electromagnetic or piezoelectric sensing of the
- 30 membrane motion in response to ambient sound. However, none of the solutions proposed proved to be satisfactory because they require very high degree of precision in making the mechanical components.

U.S. Patent No. 4,850,962 to Schaeffer proposes a mechanical to electrical transducer coupled to the tympanic membrane or some other part of the ossicular chain.

U.S. Patent No. 4,988,962 to Engebretson shows a system conveying
5 sound vibrations from the malleus to a transducer.

U.S. Patent No. 5,176,620 to Gilman describes a hearing aid which transmits electrical signals from an external microphone and transmits it to the cochlear fluid.

OBJECTIVES AND SUMMARY OF THE INVENTION

10 In view of the above-mentioned disadvantages of the prior art, it is an objective of the present invention to provide an implantable microphone which can be used in conjunction with an excitation means such as a cochlear implant to enable a patient to perceive sounds.

A further objective is to provide a completely implantable cochlear
15 implant whereby the external components of previous such aids are eliminated.

Yet a further objective is to provide an implantable microphone constructed and arranged to take advantage, as much as possible, of the patient's natural organs.

Other objectives and advantages of the invention shall be discussed in
20 the following description. Briefly, the subject application takes advantage of the fact that patients suitable for cochlear implants usually have a normally functioning eardrum and ossicular chain and consequently the fluid within the patient's cochlea responds to external sounds the same way as in a normal person. The deficiency in these persons is related to the nervous system
25 receiving signals from the fluid. Advantageously, in the present invention, the normally occurring pressure variations within the cochlear fluid are translated into electrical signals by a microphone in communication with the fluid pressure and transmitted to the cochlear implant for further processing. The pressure variations are transmitted efficiently to the microphone due to the rigidity of the
30 seal of the round window. The cochlear implant then generates corresponding excitation signals representative of external sounds which are used to stimulate the cochlear nerve.

The microphone is disposed either at an interface with the cochlear fluid, or it is immersed in the cochlear fluid itself. Alternatively, the microphone may be disposed remotely of the cochlear fluid and a conduction means is provided from the fluid to the microphone.

5 BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a cross-sectional view of an implanted microphone in accordance with the present invention;

Figure 2 shows a cross-sectional view of a first alternate embodiment of the subject invention;

10 Figure 3 shows a cross-sectional view of a second alternate embodiment; and

Figure 4 shows a cochlear implant system using the microphone of Figure 3.

DETAILED DESCRIPTION OF THE INVENTION

15 In this application the term microphone shall be used generically to designate a device for transducing variations in the pressure of a fluid into corresponding electrical signals.

Figure 1 shows a cross-sectional somewhat diagrammatic view of a patient's ear 10. The ear 10 includes the pinna 12, a tympanic membrane 14, 20 ossicles 16, labyrinth 18, scala vestibuli 20, helicotrema 22, scala tympani 24, and basilar membrane 26. The scala vestibuli 20 and the scala tympani 24 are filled with a cochlear fluid 36. The middle ear 28 communicates with the scala vestibuli through the oval window 30 and with the scala tympani 24 through the round window 32. The fluid is prevented from escaping through the round 25 window 32 by a seal 34, which forms naturally after surgical implantation of the microphone and is formed largely of scar tissue.

In a normal patient, sounds are picked up by the pinna 12 and directed to the tympanic membrane 14 which cause the latter to vibrate. The vibrations of the tympanic membrane 14 are transmitted by the ossicles 16 through the oval 30 window 30 to the scala vestibuli 20. The vibrations are then transmitted to the fluid in the scala tympani 24 through the basilar membrane 26 and the helicotrema 22, to cause corresponding pressure waves. In a normal person,

the movements of the basilar membrane 26 corresponding to the pressure waves are translated by the hair cells of the organ of Corti (not shown) into nerve impulses. These nerve impulses travel through the cochlear nerve (not shown) and are interpreted by the brain as sound. As discussed above, in many patients with a sensory neural hearing deficiency or impairment, this path is still intact and only the hair cells are non-functional. Therefore, in accordance with the present invention, the cochlear implant recreates the operation of the hair cells. More specifically, in the embodiment of Figure 1 a microphone 40A is disposed in the round window 42. The seal insures that the fluid 36 does not flow into the middle ear 28. The microphone 40A is positioned and arranged so that its sensing end 41 is in contact with the fluid 36.

The microphone 40A is connected by a wire 42 to an electronic excitation generator 44. This generator then generates signals to be perceived by the patient corresponding to the pressure variations in fluid 36 sensed by microphone 40A. The generator 44 may be implanted at any medically suitable place, for example within the head or neck of the patient.

Microphone 40A is preferably an electret or ceramic microphone encapsuled in a waterproof casing. Suitable electret (series EK or EM) and ceramic microphones (series BL) are available from Knowles Electronics, Inc., 1151 Maplewood, Itasca, Illinois 60143, U.S.A.

In an alternate embodiment of the invention shown in Figure 2, the microphone 40B is immersed in the cochlear fluid 36. Wire 42B extends from the microphone 40B through seal 34 to the electronic excitation generator 44.

In another embodiment shown in Figure 3, microphone 40C is disposed in the middle ear 28 of the patient and is connected to the generator 44 by a wire 42C. The microphone 40C is coupled to the fluid 36 by a conduction tube 46 having an open end 48. Tube 46 extends through the seal 34. Preferably tube 46 is free of any air or other gases which may attenuate vibrations sensed in the fluid 36. For this purpose, initially on implantation, the tube 46 is preferably filled with a sterile liquid such as poly-vinyl-alcohol (PVA) silicone rubber, or poly-lactic-acid (PLA). After insertion of the tube 46 into the fluid 36, the PVA is dissolved by the fluid 36. Alternatively, gel-like materials such as

silicone rubber which are bio-compatible and do not become liquid in-vitro, can be used, so long as care is taken to select a substance with a close mechanical impedance match to that of the cochlear fluid.

The excitation generator 44 can be any generator suitable for providing
5 electrical signals to the patient indicative of sounds based on vibrations from the cochlear fluid 36. A specific embodiment wherein the generator is a cochlear implant is shown in Figure 4. In this Figure, an implanted signal processor and electrode simulator 50 is provided in a common housing, which is connected to a microphone 40D by a wire 42D. Microphone 40D is disposed in the middle
10 ear, like in the embodiment of Figure 3. Of course the implant 50 works as well with microphones disposed in the round window 32, as shown in Figure 2, or immersed in the cochlear fluid 34, as shown in Figure 2.

As is common with such cochlear implants, implant 50 is also provided with an electrode array 54 extending into the scala tympani 24 as shown. The
15 array 54 is provided with a plurality of spaced electrodes 56. Advantageously, electrode array 54 has a hollow tubular shape to define a lumen 58. The lumen 58 terminates adjacent to the sensing surface 41 of microphone 40D to allow the microphone 40D to sense the fluid pressure within the lumen 58. Preferably the lumen 58 is formed with a gap 60 to allow the cochlear fluid 36 to fill the
20 lumen. At implantation, the lumen may be filled with a material such as PVA as discussed above in relation to Figure 3. A cable 62 extends from the implant 50 and its conductors are imbedded into the electrode array 54 to provide conduction between the implant 50 to the electrodes 56.

In an alternate embodiment of the invention, the hole 60 may be replaced
25 by different shaped aperture, or by a plurality of much smaller holes, which may prevent the formation of scar tissues. Scar tissues are undesirable on the hole 60 because they may attenuate the pressure variations.

In yet another embodiment, the lumen may be separated from the cochlear fluid by a permeable membrane 60A which also may prevent scar
30 tissue from growing up through the gap into the lumen. The membrane must be fabricated from a non-osmotic material in order to prevent the build up of an osmotic potential across the membrane, and any associated adverse

physiological affects.

In the embodiment of Figure 4, external sounds produce pressure vibrations in the fluid 36. These pressure variations are sensed by microphone 40D through lumen 58 and hole 60 and result in corresponding electrical
5 signals from the microphone 40D to the implant 50. The implant 50 processes these signals and generates nerve stimulating or excitation signals which are transmitted to the electrodes 56 by cable 62. The electrodes 56 apply these signals to the cochlear nerve (not shown).

If the round window is unsuitable, a microphone 40E may be placed in a
10 surgically created hole 34E in the cochlea, or in the scala vestibuli as shown in phantom lines in Figure 2.

Although the invention has been described with reference to several particular embodiments, it is to be understood that these embodiments are merely illustrative of the application of the principles of the invention.
15 Accordingly, the embodiments described in particular should be considered exemplary, not limiting, with respect to the following claims.

CLAIMS

1. A system for aiding a person having hearing deficiency, said system comprising:

a microphone for implantation into the patient, said microphone being constructed and arranged to sense pressure variations in a cochlear fluid of the patient, and to generate corresponding electrical signals; and

generator means for generating excitation signals for said patient corresponding to said electrical signals.

2. The system of claim 1 wherein said microphone is disposed in an opening of the cochlea of said patient.

3. The system of claim 1 wherein said microphone is immersed into said cochlear fluid.

4. The system of claim 1 wherein said patient has a body cavity containing said cochlear fluid, and wherein said microphone is disposed outside said cavity.

5. The system of claim 4 further comprising a tube extending from said microphone to said fluid for transmitting said pressure vibrations to said microphone.

6. A cochlear implant system comprising:

an implanted microphone constructed and arranged to sense pressure vibrations in a cochlear fluid of said patient to generate electrical signals indicative of said pressure variations;

electrode means for excitation of a cochlear nerve of said patient; and

signal processing means receiving said electrical signals to generate corresponding excitation signals for said electrode means.

7. The system of claim 6 wherein said microphone is disposed in the middle ear.
8. The system of claim 7 further comprising a conduction tube and extending from a body cavity containing cochlear fluid to said microphone for transmitting said pressure vibrations.
9. The system of claim 8 wherein said cavity is the scala tympani.
10. The system of claim 8 wherein said cavity is the scala vestibuli.
11. The system of claim 6 wherein said electrode means is a tubular electrode.
12. The system of claim 11 wherein said tubular electrode extends from said microphone to a cavity containing cochlear fluid.
13. The system of claim 12 wherein said tubular electrode is formed with a gap to allow cochlear fluid to enter into said tubular electrode.
14. The system of claim 12 wherein said tubular electrode is formed with several holes to allow cochlear fluid to enter into said tubular electrode.
15. The system of claim 12 wherein said tubular electrode is formed with a permeable membrane to allow pressure changes, to be transmitted.
16. A method of producing excitation signals for a patient having a hearing deficiency, said electrical signals being indicative of ambient sounds comprising the steps of:
 - implanting a microphone inside a patient such that said microphone senses pressure variations in a cochlear fluid of said patient;

generating electrical signals with said microphone indicative of said pressure vibrations; and

processing said electrical signals to generate said excitation signals.

17. The method of claim 16 wherein said microphone is disposed in a round window.

18. The method of claim 16 wherein said microphone is implanted in the scala tympani of the patient to immerse said microphone in cochlear fluid.

19. The method of claim 16 wherein said microphone is implanted into the scala vestibuli.

20. The method of claim 16 wherein said microphone is inserted into the middle ear of the patient, with a tube extending from said microphone to said cochlear fluid to transmit said vibrations.

21. The method of claim 16 further comprising the step of implanting a cochlear signal processor in said patient, said cochlear signal processor receiving said electrical signals and generating said excitation signals in response.

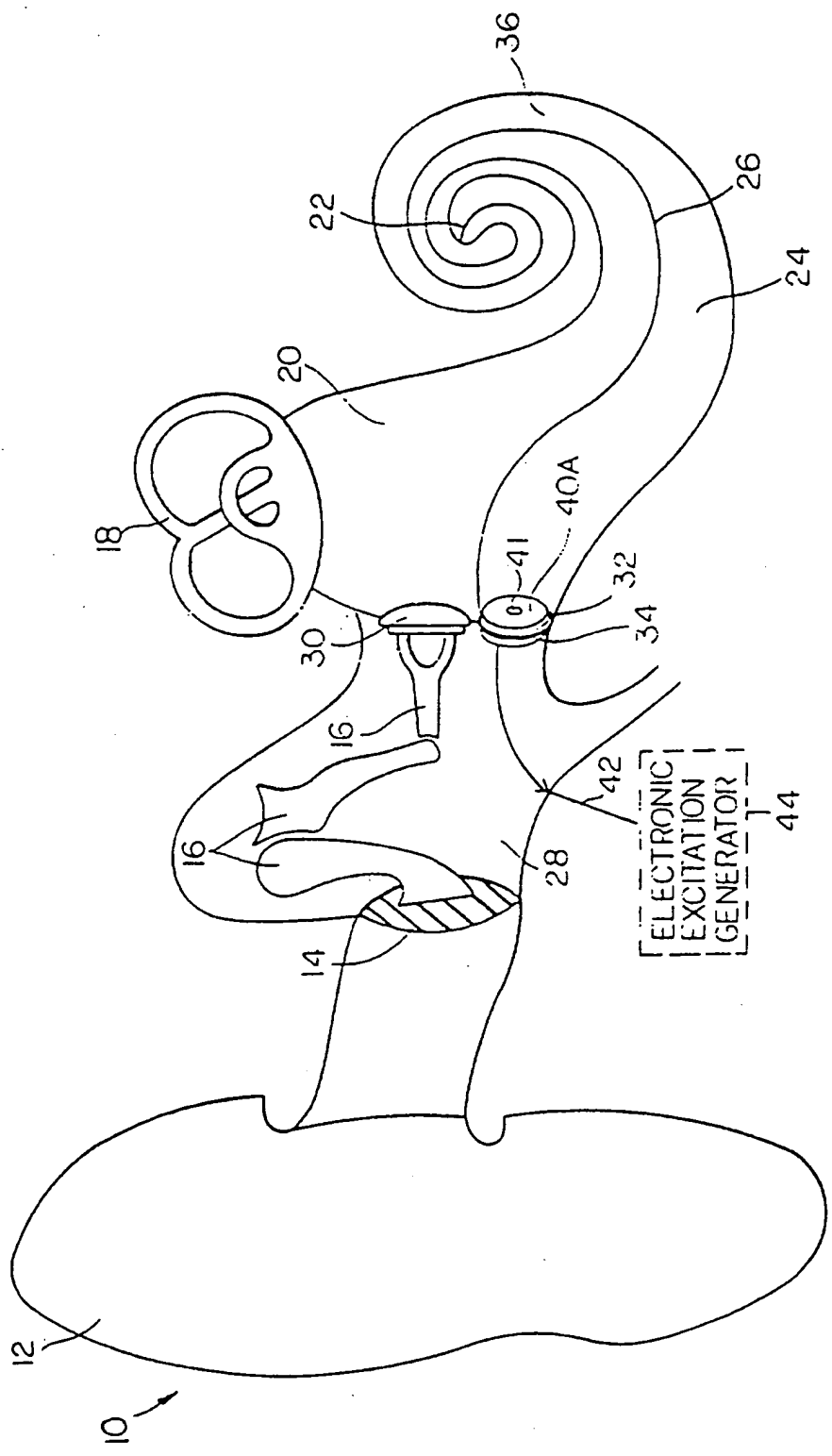


FIG. 1

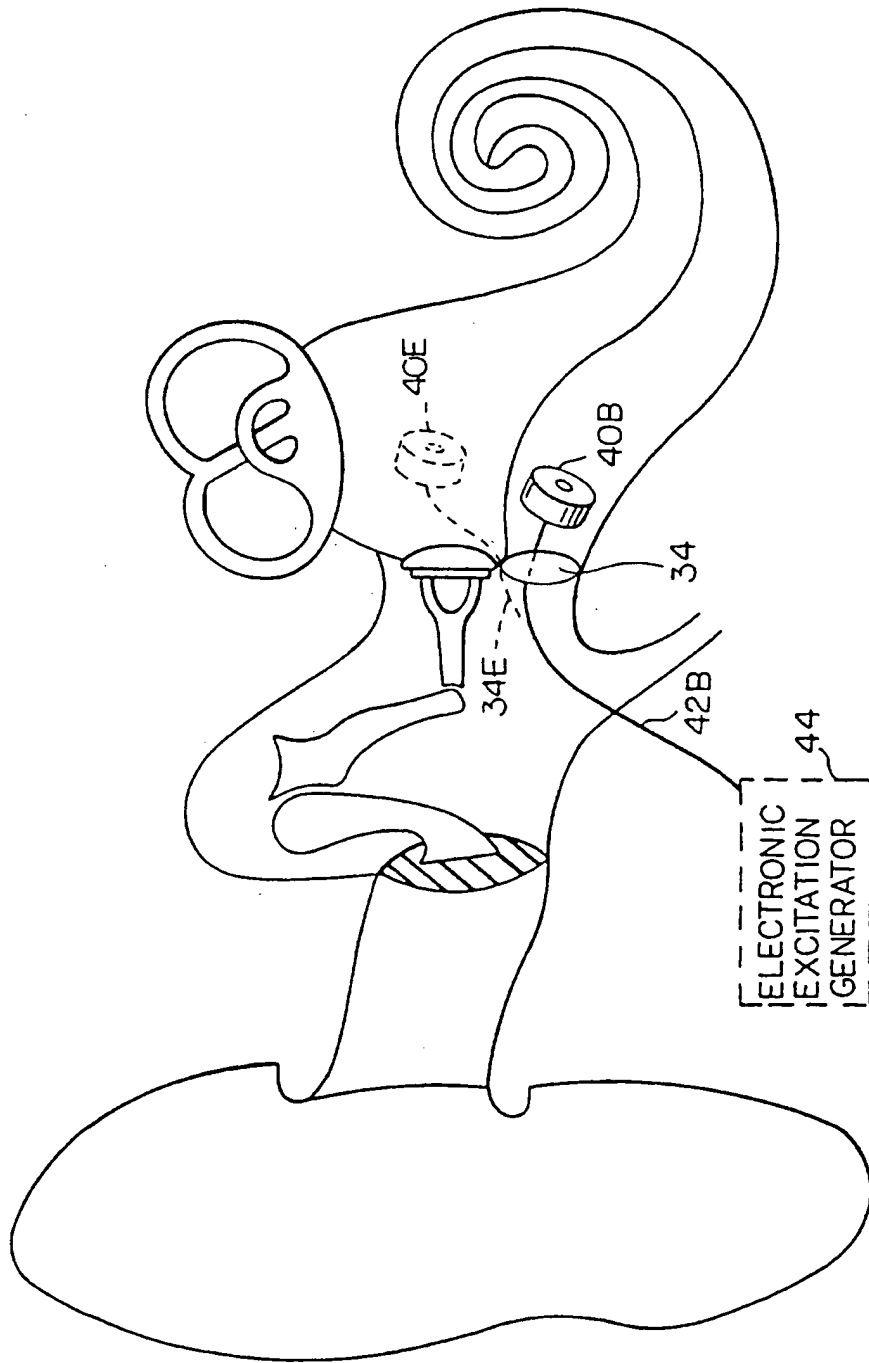


FIG. 2

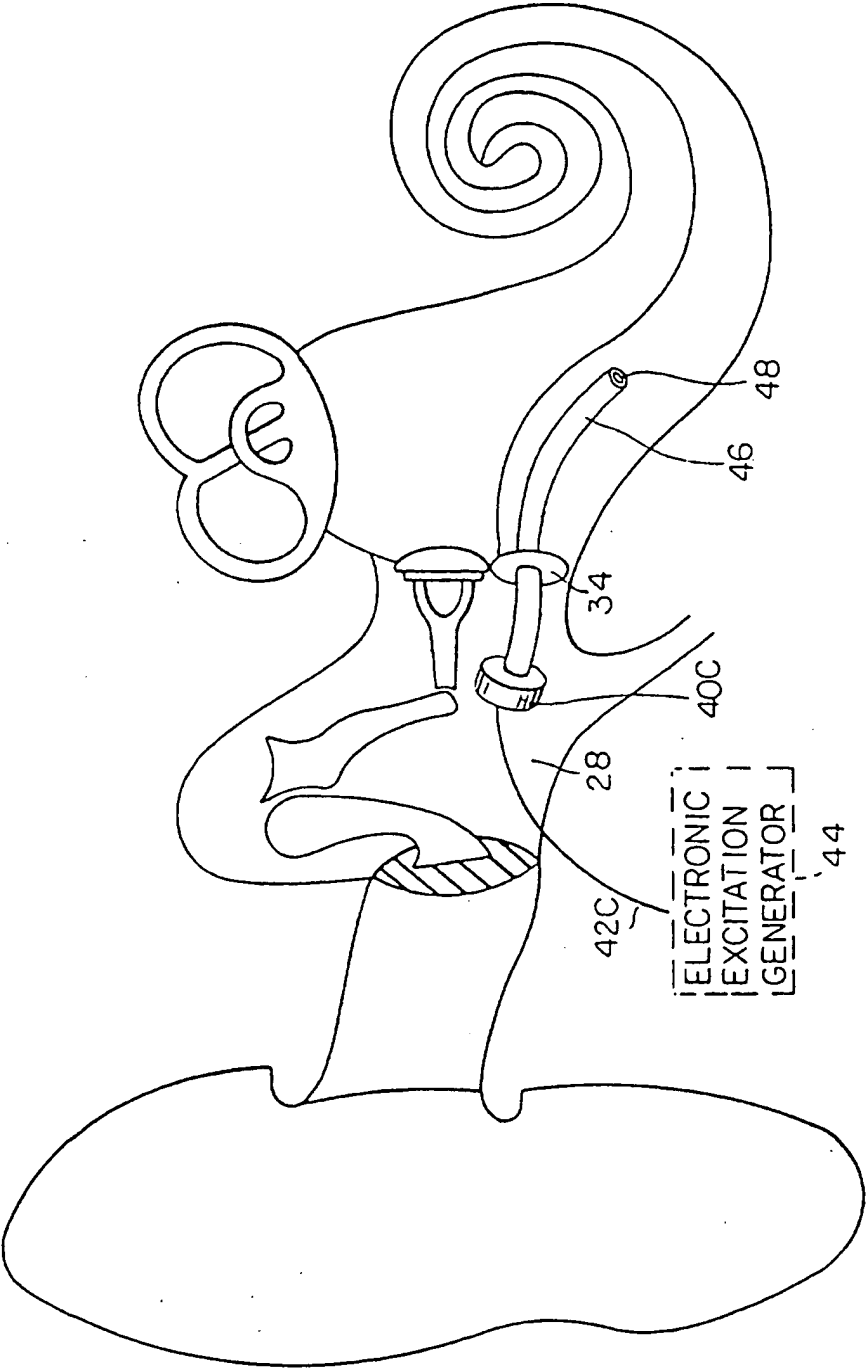
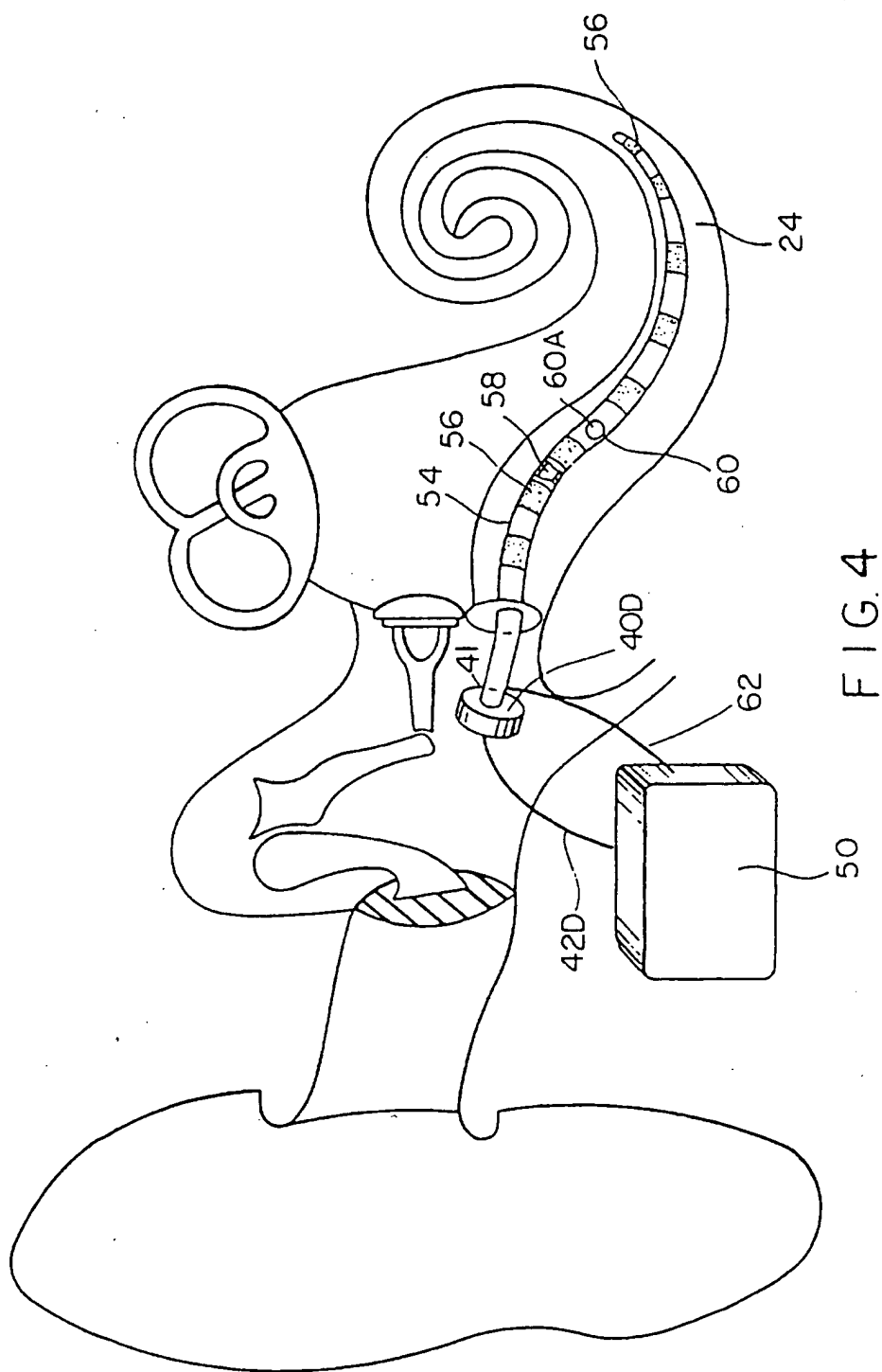


FIG.3

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INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 95/00753

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl⁶: H04R 25/00 A61F 2/18, 11/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC : H04R 25/00 A61F 2/18, 11/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

AU : IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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CAPRI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US. 5344387, A (LUPIN) 6 September 1994 column 4, line 34 to column 5, line 56, figure 5	1, 3, 6, 16, 18, 21
Y	WO. 91/05523, A (JACOBS) 2 May 1991 page 5, lines 11 to 31, page 11 line 32 to page 14 line 20, page 16, lines 6 to 25	1, 3, 6, 16, 18, 21
A	DE. 4221866, A (HORTMANN) 5 January 1994 whole document	1, 6, 16



Further documents are listed in the continuation of Box C



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C (Continuation)

DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, 5176620, A (GILMAN) 5 January 1993 whole document	1, 6, 16
A	US, 4850962, A (SCHAEFER) 25 July 1989 whole document	1, 6, 16
A	US, 4207441, A (RICARD et al.) 10 June 1980 whole document	1, 6, 16

Information on patent family members

International Application No.
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This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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